A hierarchical model of the impact of RFID practices on retail supply chain performance

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Abstract

This study aimed to evaluate the impact of RFID practices on retail supply chain performance. Empirical data was collected via an online survey of 300 retail companies, with 43.3% response rate. A hierarchical regression model was developed with eight RFID practices (warehouse, central warehouse, local warehouse, store, Standards, Transportation, Pallet, and software) as independent variables and eight supply chain performance variables as dependent variables.
RFID impacted all supply chain variables (Plan, Forecasting, Source, Replenishment, Ordering, Distribution & Delivery, Store Operations, and Sales & Returns), except Forecasting. Supplier Stock Availability (45.4%), and Wastage at Stores (42.2%) showed the highest impact.

Keywords: RFID, Supply Chain Performance, Key Performance Indicators, Retailing, Technology Adoption

Introduction

Advanced technologies such as Radio Frequency Identification (RFID) have being increasingly used in industrial, medical and consumer segments to optimize wireless communications and have a potential to solve managerial problems of developing and implementing operations plans and systems. Various market research reports predict the growth in the manufacturing of RFID tags and their increased market acceptance. RNCOS (2010) in their research report predicted the growth rate in acceptance of RFID to approximately $9.7 billion with a *Compound Annual Growth Rate* (CAGR) of 17% from 2010-13.

Increased competition and advances in information technologies push for considerable structural changes in retail supply chains (Vlachos, 2004; Fearne and Hughes, 2000). Though the benefits of RFID technologies are quite well known, empirical research indicates that they have limited applications retail supply chain. Therefore, there is a gap in our understanding how retail managers perceive the impact on RFID on supply chain performance. The aim of this study was to examine how RFID implementation in different stages of the retail supply chain may impact the performance of the supply chain. To measure the supply chain performance, several performance models were reviewed and a hierarchical regression model of performance indicators was adopted.

Literature Review

RFID applications in supply chain

There is consensus that RFID offers abilities in managing supply chains such as unique identification of products, intelligent communication and real-time information (Zhang et al., 2012). These abilities affect all areas of supply chain such as warehouse management, transportation management, production scheduling, order management, inventory management and asset management systems (Bourlakis et al., 2011; Li et al. 2010). Specific supply chain operations such as tracking, shipping, checkout and counting become more reliable and faster with RFID technology providing accurate and timely data for managing the information flows, which in turns leads to improved material flow and inventory management (Zeimpekis et al., 2008; Dai and Tseng, 2012). Moreover, RFID systems offer a wealth of supply chain-related data and information that are used for improving the planning and control of supply chain operations (Blecker, and Huang, 2008; Ngai et al. 2010).

There is a number of benefits from RFID adoption in retail supply chains. RFID can be used for tracking merchandise and inventory (Wamba et al., 2008) on assets like pallets, cases, or bins wherein real time data collection is made possible unlike barcodes which require line-of-sight to read information (Tajima, 2007). Senauer and Seltzer (2010) identified that RFID enablement at store helps in reducing out of stock merchandise through improved inventory control. Gaukler (2010) pointed out that RFID improves product availability and thereby improves overall profitability and store performance. RFID can also be used to intelligently exchange information with customers at store (Muller-Seitz et al., 2009). Such an enablement with integrated electronic displays can also improve in-store customer experience (Hinkka, 2012). Additionally, store managers can understand customer buying behavior and shopping pattern better, which in turn increases actual sales (Bertolini et al. 2012; Kholod et al., 2009).

Supply Chain Performance

Improving supply chain performance has become one of the critical issues for sustaining competitive advantages for companies (Cai et.al. 2009; Estampe et.al, 2013). Key performance indicators (KPI) used in supply chain performance evaluation have been designed to measure operational performance, evaluate improved effectiveness, and examine strategic alignment of the whole supply chain management (Gale et al., 2009; Chan and Qi, 2003). Various studies have examined different KPIs using frameworks like Supply Chain Operations Reference (SCOR) and Balanced Score Card (BSC). The SCOR model gives emphasis on operational process and includes customer interactions, physical transactions, and market interactions. SCOR arranges chain performance measurements in levels of hierarchical structure. Level 1 consists of five supply chain processes: Plan, Source, Make, Deliver, and Return. Since its introduction in 1996, the SCOR model is being increasingly adopted by companies to improve supply chain (Huang et al., 2005).

RFID impact on SC Performance

Sari (2010) pointed out that suppliers can use real time sales data from stores to reduce overall inventory cost, thereby confirming that RFID is possibly explored more for collaborative supply chain rather than for traditional ones. An example for operational process improvements is the complete elimination of shelf inspection at Wal-Mart stores (Seideman, 2003). Bendavid et.al. (2009) argued that adopting RFID to create automatic self-service stores generates considerable benefits by reducing human resource effort to perform non value added activities. Similar, RFID enablement at a warehouse would enable the team to move towards optimized delivery from traditional batch delivery models (Vlachos, 2013).

Wilding and Delgado (2004) analysed RFID implementations in warehouses or distribution centers within Marks and Spencer, Scottish Courage and Wal-Mart and its impact on improving supply chain performance in notable areas such as fulfillment lead times, inventory availability, reduction of shrinkage, etc. following the RFID implementation. Ganesan et.al. (2009) identified the need to collect cross channel customer information across these sales channels' through adoption of RFID and combine the insight about customer with suppliers' capabilities to bring about innovation in the supply chain.

Research Methods

Research design

In order to develop a robust model linking RFID practices and supply chain performance, we drew our sample from large retail companies across the globe. Having obtained positive response, a questionnaire, which had initially pretested by interviewing experts, was sent out to 300 retail companies via an online questionnaire. The questionnaire was sent to retail business managers. Screening questions filtered those who possessed adequate knowledge of RFID applications. Respondents were from all over the world, including the Americas (26%), Europe (30%); and Asia (30%). 130 usable questionnaires were returned and the response rate was 43.3%. To ensure that the respondents were comparable to non-respondents, analyses of variances were conducted between these groups. The non-response bias was assessed by comparing early respondents with late respondents (Armstrong and Overton, 1977).

Measures

We used eight RFID variables. The first four variables measured the application of RFID in a specific location across the supply chain (Supplier's warehouse; Retailer's central warehouse; Retailer's local warehouse; Retailer's owned store) and the other four variables the utilization of RFID enablers (standards, transportation, pallet level, specialized software). Supply chain performance was measured with eight key performance indicators based on the SCOR model:

Plan, Forecasting, Forecasting, Source, Replenishment, Ordering, Distribution & Delivery, Store Operations, and Sales & Returns. Each KPI was measured with two or three measures and in total seventeen supply chain performance measures were used. All variables were measured on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Since both the KPI measures and the eight predictor variables were self-reported on the same survey instrument, both measures share common methods variance. We used the Harmon's factor test to examine common methods variance and nine factors emerged, with the first factor only accounting for 26.772% of the variance. Thus, common method variance is unlikely to bias this sample.

Results

Univariate analysis

Table 1 presents the Pearson's correlation analysis. The control variable (sales) showed low correlation with the performance variables as well as with every single RFID variable. On the contrary, almost all supply chain performance variables were associated to some extent with RFID practices, except from transportation (F6).

Having automated Supplier's warehouse with RFID (F1) showed significant association with three performance variables: Perceived Distribution & Delivery [Supplier delivery lead time] (r=.-.207, p<.05), Store Operations [Percentage of Shrinkage] (r=.183, p<.05), Sales & Returns [On Time Fulfilment of customer orders] (r=.271, p<.01). Retailer's central warehouse (F2), (F4), (F5) (F8) showed no significant association with KPI variables. Retailer's local warehouse (F3) had significant association with perceived Overall Supplier performance (r=.306, p<.01). Transportation (F6) had significant association with Replenishment [Inventory in transit] 8, r=-.239, p<.01) Sales & Returns [Percentage Increase in sales across channels] (r=-.296, p<.01). Pallet level (F7) had significant association with perceived Overall Supplier performance 6 (r=-.219, p<.05) and Replenishment [Inventory availability – Days of stock cover] (r=-.201, p<.05).

Table 1 Means, Standard Deviations and Correlation Matrix

Variables	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**
Mean	5.297	5.492	4.356	5.492	5.068	6.314	5.593	7.042
Std. Deviation	2.412	2.435	2.537	2.195	2.29	2.466	2.005	1.993
Employees	0.069	-0.001	-0.09	0.024	-0.061	-0.09	0.025	0.067
Category Planning	-0.104	0.081	0.001	0.016	0.112	-0.049	-0.165	0.175
Financial Planning	0.041	-0.016	-0.057	-0.157	-0.055	-.211*	-0.137	0.088
Stock Forecast	0.172	0.008	0.023	0.102	-0.009	-0.101	-0.124	0.164
Forecasted	0.031	-0.039	-0.173	-0.104	-0.05	-0.062	-0.117	0.077

Purchases								
Purchases	0.158	-0.116	-.306**	-0.069	-0.144	-.361**	-.219*	-0.014
Overall Supplier Performance	-0.16	-0.009	0.092	0.107	0.154	0.123	-.201*	0.05
Inventory Availability	0.139	-.182*	-0.171	-0.058	-0.101	-.239**	0.116	-0.032
Inventory In Transit	-.190*	0.149	0.075	-0.029	-0.064	-0.077	-0.11	0.12
Supplier Stock Availability	-0.023	-0.028	-0.087	-0.003	-0.098	-0.139	-0.138	0.015
Lead Time	-.236*	0.172	0.143	0.055	0.165	0.132	0.018	0.173
Warehouse Speed	0.152	0.016	-0.06	0.064	-0.005	-0.175	0.05	-0.077
Supplier Lead Time	-.207*	0.096	0.168	0.006	0.128	0.058	-0.066	0.089
Wastage At Stores	-.183*	-0.018	-0.074	-0.086	-0.097	-0.152	-0.066	-0.022
Average Safety Stock Levels	0.061	-0.168	-.209*	-0.056	-0.18	-.296**	-0.096	-0.034
Sales Increase	0.107	-0.127	-0.064	-0.09	-0.066	-0.025	-0.084	-0.025
Order Fulfilment	-.271**	0.113	0.088	-0.031	.230*	0.079	-0.067	0.089

Hierarchical regression

We conducted hierarchical multiple regression to determine the best linear combination of RFID practices for predicting supply chain performance. We entered variables in three steps (Figure 1). Initially, we entered the control variable (Firm size, measured by the number of employees) in Step 1 of the regression equation. In Step 2, we entered the eight RFID practices into the regression equations. Finally, in Step 3, we entered the 28 interactions of the eight factors into the regression equations. Hierarchical regression results of RFID practices on the eight KPI supply chain performance measures are reported in the summary **Table 2**.

The combination of RFID practices in Step 2 significantly predicted The Plan performance variables. The beta weights, suggest that F1, F5, F7, F8 contribute most to predicting perceived overall supply chain performance. The change in adjusted R square value was for Category Planning .161, $p<.01$ ($F=2.390$, $p<.1$) and for Financial Planning .130, $p<.01$ ($F=1.913$, $p<.1$). These values indicate that 16.1% and 13% of the variance of PLAN performance was explained by the model.

The changes in adjusted R square values in Step 2 and Step 3 for Forecasting variables were not significant. In sharp contrast, the changes in the model with Source performance variables were significant. In particular, in Step 2, the entering of 8 RFID variables resulted in a change in adjusted R square of a value of .216 $p<.001$ ($F=5.7111$, $p<.001$) for Purchases and .199 $p<.01$ ($F=3.076$, $p<.01$) for Overall Supplier Performance respectively. In Step 3, were all interactions of RFID variables were entered in the equation, the change in adjusted R square values increased to .363 p<.01 (F=2.836, p<.001). This indicates that RFID implementations may result in improvement of sourcing performance from 21.6% to 36.3%.

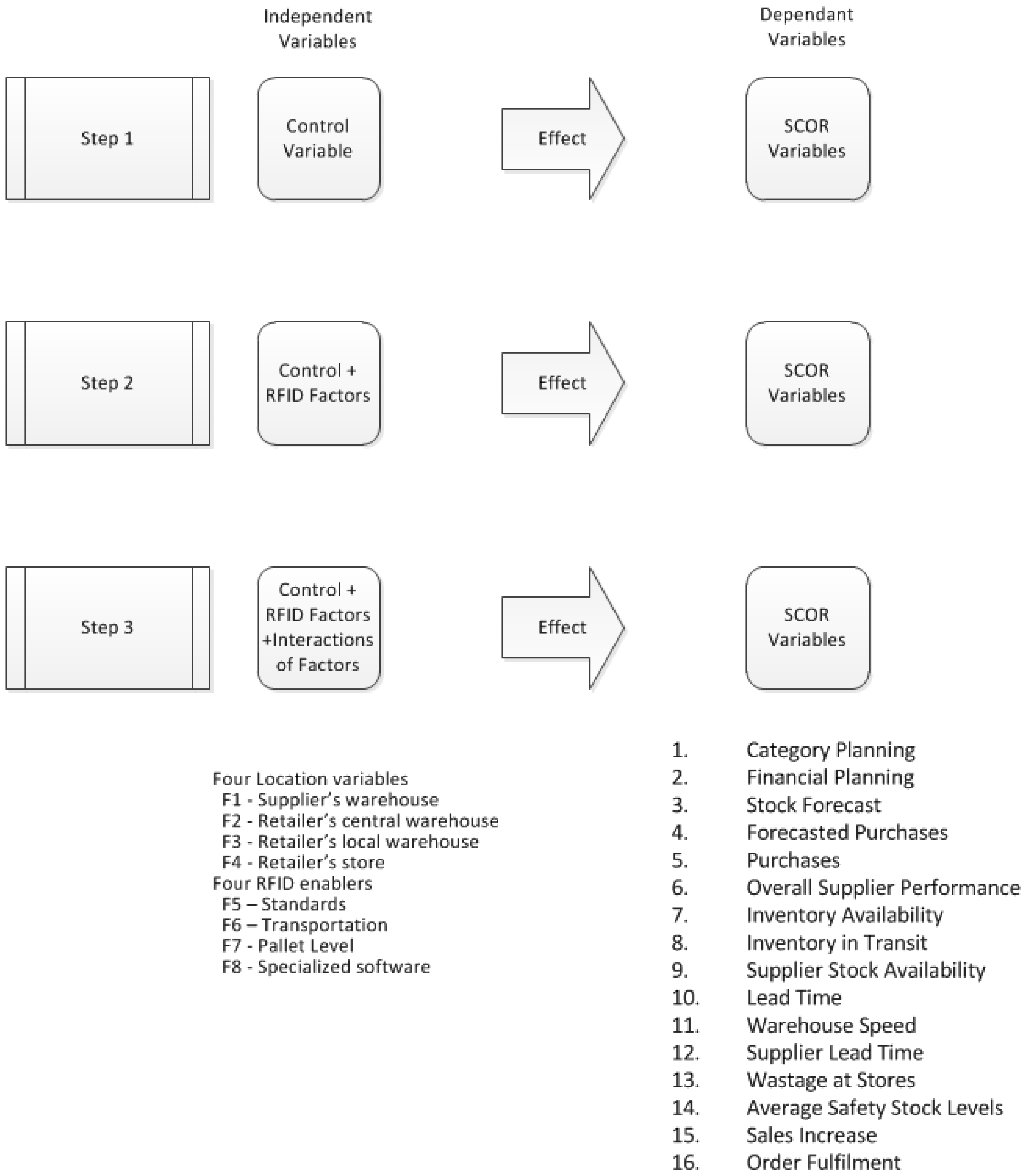

Figure 1 Hierarchical Regression Model

Table 2 Summary of Findings

Performance Measure	**F**	**Adjusted Rsquare**	**Change in**	**F**	**Adjusted Rsquare**	**Change in**

	Step 2			Step 3		
Supplier Stock	0.996	0	0.066	2.448***	0.314	0.454***
Waste At Stores	0.928	0	0.071	2.111**	0.26	0.422**
Sales Increase	0.777	-0.01	0.05	1.862*	0.214	0.401**
Overall Supplier	3.076**	0.137	0.199**	2.836***	0.367	0.363**
Stock Forecast	1.59	0.043	0.113*	1.889**	0.219	0.349*
Supplier Lead Time	2.723**	0.117	0.122*	2.036**	0.246	0.300*
Order Fulfillment	5.317***	0.249	0.204***	2.839***	0.367	0.260*
Forecast Order	0.888	0	0.068	1.163	0.049	0.28
Category Planning	**2.390***	**0.096**	**0.161***	**1.584***	**0.155**	**0.256**
Inventory In Transit	2.640**	0.112	0.170**	1.673*	0.175	0.255
Average Safety Stock	2.230*	0.086	0.147*	1.323	0.092	0.222
Warehouse Speed	1.285	0.021	0.087	0.945	-0.01	0.207
Financial Planning	1.913*	0.065	0.130*	1.1	0.03	0.199
Purchases	5.711***	0.266	0.216***	2.273**	0.287	0.19
Lead Time	2.781**	0.12	0.168**	1.241	0.07	0.176
Inventory Availability	3.659***	0.169	0.167**	1.452*	0.125	0.168

For replenishment variables, there was a significant changes in adjusted R square value for Inventory Availability .167 p<.01 (F=3.659, p<.001) and for Inventory in Transit .170 p<.01 (F=2.640, p<.001). This indicates that about 17% improvement of replenishment due to RFID implementation. The hierarchical modeling of Ordering resulted in unique findings. In particular, Step 2 for Supplier Stock Availability showed no significant findings, yet Step 3, there was a significant in change of adjusted R square value of .454 p<.001 (F=2.448, p<.001). For Lead Time, only Step 2 had significant change in adjusted R square value of .168 p<.01 (F=2.781, p<.01). This indicates that when RFID is widely used across the supply chain, there is a 45.4% improvement in stock availability.

Supplier Lead Time showed a significant change in adjusted R square value of .122 p<.01 (F=2.723, p<.01) in Step 2 and .300 p<.1 (F=2.036, p<.01) in Step 3, respectively. Regarding Store Operations, Wastage at Stores had a very significant change in adjusted R square value of .422 p<.001 (F=2.111, p<.01) in Step 2 and Average Safety Stock Levels a change of .147 p<.001 (F=2.230, p<.1) in Step 3. Sales Increase had a very significant change in adjusted R square value of . 401 p<.01 (F=1.862, p<.1) in Step 3 and Order Fulfillment a change of .204 p<.001 (F=5.317, p<.001) in Step 2 and .260 p<.1 (F=2.839, p<.001) in Step 3.

Discussion & Conclusions

This study contributes to both the RFID and supply chain performance literatures in a number of ways. Firstly, all KPI variables, except Forecasting, showed a significant relation to RFID variables. The hierarchical models showed that there was no single RFID variable that contributes significantly to supply chsin performance. On the contrary, when all RFID variables were entered, in Step 2, in the regression equation, then they produced significant and statistically power results. In some cases, the combination of all variables and their interactions (Step 3) produced significant results too, yet there is less statistical power when a regression equation has 37 independent variables (the control, the eight RFID variables, and their interactions) than nine (all but the interaction variables). As expected, the RFID implementation has no significant effect on demand forecasting. However, it has significant effect on Supplier Stock Availability (45.4%), Wastage At Stores (42.2%), Sales Increase (40.1%), and Overall Supply Performance (36.3%). These results show that over 47.5% of the variance of supply chain performance is explained by the model. According to Cohen (1988), this is a large effect. Through the implementation of RFID, retailers and their suppliers have access to more accurate and detailed knowledge of inventory, demand and supply history.

Although an increase of 40% should be considered as huge improvements in supply chain performance, lower percentages are not neglectable. In particular, RFID had significant impact on Order Fulfillment (26%) Purchase (21.6%), Source Replenishment (17%), Lead Time (16.8%), and Supplier Lead Time 12.2%. By providing more clarity of information about KPIs across the supply chain, managers can make more accurate decisions more quickly. These in turn allowed for production lead time to be reduced.

One limitation of the findings is the use of self-report questionnaires to collect data on all measures. This limits our ability to draw conclusions about the causal nature of the relationships. Despite these limitations, this study provides evidence regarding the effects of RFID on supply chain performance and suggests that RFID needs to be applied widely across the supply chain in order to increase performance even at high levels such as 40%.

However, this wide application of RFID needs the necessary technical infrastructure including standardization of data exchanges and application of proper software applications. RFID technology is in its early phases of adoption. Supply chain members are just in the beginning of the adoption phase where they evaluate the benefits that this technology can provide in improving operations, reducing costs, and improving customer satisfaction. As is the case of any new technology adoption, managers must consider the relative advantage of this technology and how it fits to their organizational culture. However, as an inter-organizational technology, RFID can bring mutual benefits to more supply chain partners, therefore the key performance indicators need to include a wider spectrum of supply chain activities.

As the development and implementation of RFID technology has been one of the most widely discussed topics, the findings of this research may be very helpful for business managers in manufacturing, 3rd Party Logistics providers, retailers as well as small and medium-size suppliers. The first major managerial implication is that, given that the RFID impact on performance indications such as inventory management are 40%, RFID adoption can provide a source of sustainable competitive advantage. These potential performance improvements will attract more companies in the near future and increase the competitive around RFID implementations. With the help of this study, supply chain managers can better understand how RFID adoption impacts on eight different supply chain areas. The detailed analysis (change in r squares, F-power, and beta-values) can provide insights on how different RDID combinations would impact supply chain performance. Then, this study uncovers that RFID technology may drive the direction of future collaborative relationships among supply chain members. RFID requires a common understanding of various technological parameters, such as tags, software and data standardization. Thus, as more and more companies introduce RFID in their supply chain practices, the more the collaborative practices would depend on the RFID specific implementation. Retailers with a leading position in chain integration may play a pivotal role in the evolution of supply chain practices towards encompassing advanced technologies including RFID.

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